TITLE: Comparison of short-term energy intake and appetite responses to active and seated video gaming, in 8 to 11 year-old boys.

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ABSTRACT

The acute effects of active and seated video gaming on energy intake (EI), blood glucose, plasma glucagon-like peptide-1 (GLP-1_{7-36}) and subjective appetite (hunger, prospective food consumption and fullness) were examined in 8-11 y boys. In a randomised, crossover fashion, 22 boys completed one, 90 min active and one, 90 min seated video gaming trial during which food and drinks were provided *ad-libitum*. Energy intake, plasma GLP-1_{7-36}, blood glucose, and subjective appetite were measured during and following both trials. Time averaged AUC blood glucose was increased (p=0.037) however, EI was lower during active video gaming (1.63±0.26 MJ) compared to seated video gaming (2.65±0.32 MJ) (p=0.000). In a post-gaming test meal 1 h later, there were no significant differences in EI between the active and seated gaming trials. Although estimated energy expenditure (EE) was significantly higher during active video gaming, there was still no compensation for the lower EI. At cessation of the trials, relative energy intake (REI) was significantly lower following active video gaming (2.06±0.30 MJ) versus seated video gaming (3.34±0.35 MJ) (p=0.000). No significant differences were detected in time averaged AUC GLP-1_{7-36} or subjective appetite. At cessation of the active video gaming trial, EI and relative EI was significantly less than for seated video gaming. In spite of this, the relative EI established for active video gaming was a considerable amount when considering the total daily EAR for 8-11 y boys in the UK (7.70 MJ).

INTRODUCTION

In England, one sixth of children aged between 2-10 y are estimated to be obese [1]. Peak incidence of obesity appears to be during mid-to-late childhood, when aged between 7 and 11 y, particularly in boys [2]. Physical activity (PA) in childhood is key as it lowers the risk of obesity and the related chronic and life-limiting conditions such as cardiovascular disease and type 2 diabetes [3]. The most recent data for England indicates, that only 18.5% of children are achieving at least 60 min of moderate to vigorous physical activity (MVPA) per day [1]. Moreover there is evidence of a decline in PA as children progress into adolescence [1; 4]. One reason for this decline in PA could be a greater use of sedentary screen based media [5].

Active video gaming could however, provide a suitable replacement to seated based video game play to potentially increase children's PA. Active video games integrate body movement (isolated limbs or whole body) into the game experience and video gaming. Movements are sensed via a hand-held motion controller (Nintendo Wii™), video cameras (Sony, Eye Toy™ and Microsoft, Xbox Kinect™) or weight-sensing platforms (Konami, Dance Dance Revolution™ and Nintendo Wii Fit™) [6]. Recent active video gaming research with paediatric groups has established that game play produces greater EE and light to moderate PA when compared with resting, television viewing and seated video gaming [7; 8; 9; 10; 11; 12]. There is also evidence that boys expend more energy that girls during active video game play [8; 13] and that they display greater enjoyment and engagement in this type of video game [13]. In view of the aforementioned findings therefore, active video game play might be more of a feasible alternative to seated video gaming for boys to increase PA levels.

In paediatric groups however, it appears that spontaneous EI both during and following sedentary screen-based media activity [14; 15] occurs, which exceeds the energy expended and this could also occur during active video gaming. Recent active video gaming research has observed that EI can exceed EE following 1 h of game play in both 13-17 y males [16] and 12-15 y obese males [17]. Furthermore, when the 13-17 y males were monitored over 24 h after the trial, there was also a down-regulation in PA following active video gaming. Consequently, similar to matched seated video gaming and resting trials, the 13-17 y males were found to be in a positive energy balance state following active video gaming [16].

Energy intake following active video game play [16; 18] however, might not be representative of children's real-life active video gaming practices particularly as there is evidence of eating during play [19; 20]. Recently and in view of this, the EI from food and drinks offered *ad-libitum* during both

active and seated video gaming was explored, in 8-11 y boys[11]. The findings of the study established that EE was significantly greater from active video game play, however EI during both trials was similar. As a result, the energy expended by active video game play, did not counterbalance the EI during it[21] yet despite this, relative energy intake (REI) at cessation of gaming was significantly lowered. In the cited study, PAEE and EI were not monitored beyond the gaming trials so it is unknown whether any compensation occurred at a later time-point. In addition, subjective appetite sensations (hunger, fullness and prospective food consumption) which were similar during both active and seated video gaming, provided no explanation for the similarity in EI [11]. Energy intake both during and following active and seated video gaming should therefore be measured. In addition, appetite should be measured objectively as well as subjectively, to explore whether homeostatic-related signals can provide an explanation for the EI during both active and seated video game play. Only one seated video gaming study thus far has measured appetite signals related to hunger, alongside subjective appetite in 15-19 y males [14]. No differences were found in total ghrelin or serum insulin between trials during seated video gaming, yet blood glucose was significantly higher. According to the 'glucostatic theory' of short-term appetite regulation a rise in glucose is indicative of a satiety response [22], yet the test meal EI of the 15-19 y males following the 1 h seated gaming bout was greater and post-gaming hunger sensations were not increased [14]. Satiety-related homeostatic signals were not measured in this earlier study [14] so it is unknown whether appetite signals related to satiety were raised. The measurement of satiety-related appetite might have provided an explanation for the increased EI following seated gaming or given an indication as to whether it may be due to hedonic mechanisms [14; 23; 24].

Due to the lack of difference in hunger-related signals during seated video gaming in 15-19 y males [14] and the similarities in EI and appetite sensations of 8-11 y boys both during active and seated video gaming, it would be pertinent to measure satiety-related appetite signals. The measurement of satiety-related signals alongside subjective appetite could provide a more in-depth understanding of the mechanisms behind the spontaneous EI observed during both active and seated video gaming. The present study therefore, aimed to assess acute EI, plasma GLP-1_{7-36}, blood glucose and subjective appetite responses during and 1 h following 90 min bouts of active and seated video gaming, in 8-11 y boys.

MATERIALS AND METHODS

Design

A randomised, crossover design was used to compare plasma GLP-1_{7-36}, blood glucose, subjective appetite and EI responses of 8-11 y-old boys, to active video gaming versus seated video gaming, each separated by 1 week. The active video gaming bouts utilised were representative of children's real-life active video gaming practices i.e. the type of active video game and console, the duration (min) and EI during gaming were identified in a previous study [19]. There were two gaming bouts: (1) 90 min of seated video gaming and (2) 90 min of active video gaming. During each gaming bout, food and drinks were offered *ad-libitum* enabling EI to be measured whilst gaming and also in a test meal 1 h later. The boys were placed into groups of two according to school year. Each group was then randomly assigned to a different bout every week so that by the end of the 2 weeks they had completed each trial.

The study was conducted according to 2013 Declaration of Helsinki (World Medical Association. 2013) [25] and was approved by the University of Northumbria, Faculty of Health and Life Sciences Ethics Committee. Written informed consent was obtained from each child's parent and assent from every boy, prior to data collection.

Participants

To recruit 8-11 y boys, consent was obtained from the head teacher of a Primary School located within the city of Newcastle upon Tyne (North East England, UK). Recruitment packs were distributed to all eligible boys who expressed an interest in participating and they were asked to take it home to their parents. The pack contained a letter addressed to their parents with a full explanation of the study and consent forms for them and their child (if able) to sign and return to school. Signed consent forms were received from 22 boys (mean age 9.9±0.2 y). Boys were excluded if they had intolerances or allergies to the foods provided in the study or had an injury or illness which prevented their play of active video games. Overall, 22 boys participated in the study.

Preliminary measures

Prior to the first gaming trial, the researchers met the children (and where applicable, their parent) at the school for familiarisation. The boys were familiarised with the gaming consoles (Nintendo Wii™), games (Nintendo Wii™ Sports, tennis) (Nintendo ©), the gaming session format, the self-reported weighed food diaries and visual analogue scales (VAS) that were used to explore subjective appetite sensations. The researchers demonstrated the right hip placement of accelerometers (Actigraph LLC © GT3X+) used for the measurement of PA during the gaming

trials. The boys were asked to complete a food preference questionnaire to ensure they did not dislike the foods and drinks offered during the study. They completed the Dutch Eating Behaviour Questionnaire for children (DEBQ-C), as a measure of dietary restraint [26]. Stature and seated height were measured to the nearest 0.01 m using a Harpenden Portable Stadiometer (Holtain Limited, Pembs, UK). Body mass was measured to the nearest 0.1 kg using portable SECA scales (SECA United Kingdom). Waist circumference was measured to the nearest 0.01 m with a non-elastic flexible tape at each boy's natural waist whilst standing as an indication of central adiposity [27].

Protocol

Each boy was provided with a self-report, weighed food diary and a set of food weighing scales (Salter ©, Kent, UK). With the help of their parent they were asked to weigh and record all foods and drinks they consumed from 1700 h the evening before, until after they had consumed breakfast on the morning of each trial day. A photocopy of the food diary was provided to each parent who was asked to replicate their child's food and drink intake prior to the second gaming trial. With the help of school staff and parents, the boys abstained from all physical education at school on the day of the study and PA from 1700 h the preceding evening.

On the trial days, the boys were met at school at 0830 h by two members of the research team and escorted to the University laboratory. On arrival (~ 0850 h), the boys rested until 0900 h when they completed baseline appetite VAS. Immediately following this (t=0 min), a finger-prick blood sample (300 µL) was taken from each boy to enable the determination of baseline plasma GLP-$1_{7\text{-}36}$ and blood glucose.

The boys completed additional appetite VAS at 45 min during gaming, at the end of gaming (90 min), 45 min post gaming (135 min) and immediately following the test meal (180 min). Further fingertip blood samples (300 µL) were taken at 45 min during gaming, at the end of gaming (90 min), 45 min post gaming (135 min) for the determination of plasma GLP-$1_{7\text{-}36}$ and blood glucose. Upon termination of each 90 min gaming trial, the boys rested for 60 min following which they were provided with an *ad-libitum* test meal, before being returned to school by the research team. A diagrammatic representation of the study protocol is provided in Figure 1.

Gaming trials

168 The design of the individual gaming trials was based on published data which described the active
169 gaming practices of 7-11 y children from Newcastle upon Tyne [19]. The active video gaming
170 console utilised was Nintendo Wii™ and the game was Nintendo Wii™ Sports tennis [19]. The
171 seated video game utilised was 'Mario and Sonic at the London 2012 Olympic Games' which was
172 played on the handheld device, Nintendo© 3DS. The two gaming trials took place on the same
173 school day of each week over two consecutive weeks. The two gaming trials were: 1) 90 min seated
174 video gaming during which food and drinks offered *ad-libitum*; 2) 90 min active video gaming
175 during which food and drink offered *ad-libitum* as they have been successfully used in previous
176 gaming and appetite work with young boys [21].

177 ***Energy intake***

178 The food and drink items provided during the gaming sessions were based on previous findings
179 [19]and comprised 130 g apples (raw, slices and cored), 50 g crisps [potato chips (Walkers©, ready
180 salted)], 250 mL semi-skimmed milk, and 250 mL 'Jucee' apple and blackcurrant squash (no added
181 sugar). All food items were pre-weighed by the researchers to the nearest gram using electronic
182 portable scales (Salter ©, Kent, UK) and all drinks were measured to the nearest millilitre. The
183 crisps and apple were placed in clear plastic bags and the milk and squash were placed in coloured
184 drinks bottles so that volumes could not be detected. All items were numerically coded by the
185 researchers and placed at a station designated to each individual boy who were offered them *ad-*
186 *libitum*. When the gaming trials commenced, the time of the first eating episode for each boy was
187 recorded. The researchers noted each bag or bottle taken by the boys and anything left over was
188 weighed or measured so that amounts consumed could be calculated and recorded. Food and drink
189 items were topped up before being finished, during the gaming bouts.

190 The *ad-libitum* test meal provided after the gaming bouts was pasta, with tomato sauce, cheddar
191 cheese and olive oil (ASDA, Leeds, UK) which was served in excess and topped up before being
192 finished. The boys were instructed to eat until they felt comfortably full, at which point the meal
193 was terminated. As they ate the test meal, the bowl was refilled by the researchers. The research
194 team covertly weighed the test meal before it was served and as the meal was terminated. The
195 macronutrient content of the meal was 58% CHO, 28% fat and 14% protein and provided 450 kJ
196 (107.5 kcal) per 100 g of total energy, similar to a pasta meal utilised in a previous adolescent
197 appetite study [28]. Energy intake for all of the food and drink items served was estimated from
198 individual food labels, an online resource (www.asda.com) and MicroDiet (Downlee Systems©,
199 Derbyshire, UK).

200 ***Physical activity assessment***

201 During both gaming bouts, the PA levels of each boy were measured by accelerometry using an
202 Actigraph© LLC, GT3X+ placed on the right hip since this is considered the optimum site for PA
203 monitoring [29]. Physical activity counts were recorded in 10 s epochs. Following each trial, the
204 accelerometer data was downloaded utilising Actilife 6 data analysis software and interpreted using
205 recommended child-appropriate activity cut-off values [30]. Activity counts were converted into
206 mean metabolic equivalents (METS) using MET thresholds recommended for use with children:
207 sedentary < 1.5 METS; light 1.5 to < 4 METS; moderate 4 to < 6 METS; vigorous > 6 METS [31].

208 ***Energy expenditure***

209 For each boy, Henry's body mass, stature and sex-specific equations were used to calculate basal
210 metabolic rate (BMR) [32]. Energy expenditure was then calculated as recommended by Ridley,
211 Ainsworth and Olds [33], as follows; METS x BMR (MJ·min·d) x 90 min gaming = MJ.

212 ***Relative energy intake***

213 For each boy, EE was subtracted from the amount of energy consumed during each 90 min gaming
214 bout and also from the test meal to calculate REI.

215 ***Subjective appetite***

216 Hunger, fullness and prospective food consumption were assessed using VAS. Questions asked
217 were: 'How hungry do you feel now?' accompanied by the statements, very hungry (0) and not at
218 all hungry (100); 'How full do you feel now?' accompanied by, very full (0) and not full at all
219 (100), and prospective food consumption ''How much would you like to eat now?'' accompanied
220 by a lot (0) and nothing at all (100). The boys were requested to place a vertical mark along the 100
221 mm horizontal lines. Scales were collected prior to the commencement of gaming (baseline t=0
222 min), at 45 min during gaming, at the end of gaming (90 min), 45 min post gaming (135 min) and
223 immediately following the test meal (180 min).

224 ***Blood sampling***

225 To obtain blood samples, the fingertip capillary blood sampling and handling method utilised by
226 Green and colleagues [34] was followed. For the measurement of GLP-$1_{7\text{-}36}$, capillary blood samples
227 were collected immediately before the gaming bouts commenced (baseline t=0 min), midway
228 during the gaming bout (45 min), at the end of the gaming bout (90 min) and at 45 min post-gaming
229 (135 min) (Figure 1). The fingertip puncture site was cleaned with an aseptic wipe then pierced with
230 a sterile automated lancet (Accu-Check, Mannheim, Germany). The blood was collected into a pre-

cooled EDTA microvette pre-treated with aprotinin (33 µL per mL) and DPP-IV inhibitor (30 µL per mL) to aid in the preservation of GLP-$1_{7\text{-}36}$. Immediately following blood collection, the microvettes were placed on ice and spun at 1500 *g* for 10 min enabling aliquots of the plasma supernatant to be pipetted into labelled Eppendorfs and stored at −80 °C for later quantification.

At the same time as blood was collected for the determination of GLP-$1_{7\text{-}36}$, a sample was also obtained from the same puncture site to establish blood glucose concentrations. Each of these blood samples (0.02 mL) was drawn into a sodium heparinised capillary tube and transferred into an Eppendorf containing 1 mL haemolysis solution (EKF Diagnostics). Samples were shaken to encourage haemolysis and then immediately placed on ice.

6.2.8 Blood analysis

Glucagon-like peptide-1 (GLP-1 $_{7\text{-}36}$) was quantified by electrochemiluminescence, utilising a human hormone multiplex assay (Sector Imager 2400, MesoScale Discovery, Rockville, MD, USA). To reduce inter-assay variation, samples from each boy were analysed on the same assay plate. The coefficient of variation (CV) was established as 5.5%. The blood glucose samples were quantified by the glucose oxidase method using an automated glucose analyser (Biosen C line, EKF Diagnostics).

Statistical analysis

Twenty one boys were included in the statistical analysis, as data for one of the boys was excluded due to his EI being different in the requested period of replication prior to the first and second trials. One more boy was unable to provide blood samples during the trials but all other data collected from him was included in the analysis. IBM© SPSS (version 22.0, SPSS Inc., Chicago, Illinois) was used for all analyses. Data was checked for normality using the using Shapiro-Wilk test and means $_{\pm \text{ SEM}}$ were calculated for all variables. Data from 20 boys was included for GLP-$1_{7\text{-}36}$ (pg/mL) and blood glucose. To establish the effect of gaming, plasma GLP-$1_{7\text{-}36}$ (pg/mL) and blood glucose (mmol/L) responses were calculated as time-averaged area under the curve (AUC) x 135 min for both gaming trials. To establish the effect of the trials on subjective hunger, prospective food consumption and fullness, VAS ratings (mm) were calculated as time-averaged AUC x 180 min. Time-averaged AUC values for plasma GLP-$1_{7\text{-}36}$ and subjective appetite sensations, along with gaming and test meal EI, gaming macronutrient EI (CHO, fat and protein), PA (METS), EE (MJ), REI (MJ), time to eating onset during gaming (min) and the ingestion time of the test meal (min) were analysed using paired t-tests. When significant differences occurred, Cohen's *d* effect size was calculated and interpreted against the effect size categories of ≤0.20 = small effect, ~0.50 =

moderate effect, and ≥0.80 = large effect [35]. Significance was set at $p< 0.05$ for all analyses. To aid in the interpretation of clinically meaningful statistical differences, time averaged AUC values x 90 min, determined from a between-variation study of fasted plasma GLP-1_{7-36} (4.8.1±0.1 pg/ml) and blood glucose (5.1±0.0 mmol/l) in 8-11 y boys, were utilised (Allsop, S., Dodd-Reynolds, C.J., Green, B.P., et al., unpublished results).

RESULTS

Population characteristics

The 21 boys were of mean $_{\pm SEM}$ stature 1.45±0.02 m, body mass 37.9±1.6 kg, with a mean waist circumference of 64.3±1.7 cm and BMI of 18.1±0.7 kg/m^2. According to UK age and sex-specific BMI centiles [36], the majority of the boys were classified as having a healthy body mass (77.3%), 9.1% were overweight and 13.6% as obese. Mean maturity offset was -0.3±0.3y, indicating that as a group the boys were 3.6 months from peak height velocity and of similar maturation status. All boys were identified as being unrestrained eaters with a mean $_{\pm SEM}$ dietary restraint score of 1.8± 0.13 categorised as being average for boys of this age (1.53±0.06) [26].

Physical activity and energy expenditure

All values for PA (METS), EE and REI are displayed in table 1. Active video gaming elicited light PA (METS) and EE which was significantly greater than the sedentary levels produced by seated gaming (all p=0.000, moderate effect size d=0.7).

Energy intake and relative energy intake

Table 2 indicates that boys consumed significantly more when seated video gaming, compared to active video gaming (small effect, size d=0.3). As a percentage of total EI (MJ), the boys consumed significantly more CHO (58.3±16.7 %, p=0.004, small effect size d=0.3) and protein (6.8±4.4 %, p=0.022, small effect size d=0.1) but less fat (36.4±14.7 %, p=0.004, small effect size d=0.3) during the active video gaming bout, than during seated video gaming (CHO 49.3±12 %; protein 6.2±2.9 %; fat 44.5±11.3 %), as illustrated in Figure 2. No significant difference was found in the average time to eating onset (min) and similar amounts of the test meal were consumed for which there was no significant difference in ingestion time (min).

As shown in Table 2, following both the active and seated video gaming bouts the boys were in a positive REI state. Relative energy intake was significantly greater due to seated video gaming than active video gaming (p=0.000, small effect size d=0.4). When accounting for the test meal, REI was

significantly greater at the end of the seated video gaming compared to active video gaming (p=0.000, moderate effect size d=0.6).

Plasma GLP-1_{7-36} and blood glucose

No significant differences were detected in baseline plasma GLP-1_{7-36} (p=0.199) or blood glucose (p=0.676) between active and seated video gaming. There were no significant differences in time-averaged AUC x 135 min for plasma GLP-1_{7-36} (Figure 3a) between active and seated video gaming (p=0.413). Time-averaged AUC x 135 min blood glucose was significantly greater during active video gaming (p=0.037, small effect, size d=0.3), in comparison to seated video gaming as illustrated in Figure 3b.

Subjective appetite

There were no significant differences in baseline appetite values for hunger (p=0.917), prospective food consumption (p=0.204) and fullness (p=0.315) between seated and active video gaming. No significant differences were detected in time-averaged AUC x180 min for hunger (p=0.884), prospective food consumption (p=0.570) or fullness (p=0.733) between the active and seated video gaming trials.

DISCUSSION

The present study was the first to rigorously explore the satiety-related signals, plasma GLP-1_{7-36} and blood glucose in response to active and seated video gaming in 8-11 y boys. *Ad-libitum* gaming EI and subjective appetite sensations were also measured during 90 min of gaming and in a post-gaming test meal, to determine whether acute compensation occurred for gaming EI.

The main findings were that the *ad-libitum* gaming EI of 8-11 y boys was significantly greater during seated than during active video gaming. Moreover, EI during both trials was a considerable proportion of daily EAR for energy, for males aged 9 y, in the UK (7.70 MJ) [37]. Time-averaged AUC blood glucose was significantly higher during the active video gaming trial (t=0 min to 135 min). Upon examination of the macronutrients revealed during the 90 min active video gaming bout, the boys were found to have consumed a greater proportion of CHO during this trials, even though overall EI was more when seated. The substantial EI during 90 min of both seated and active gaming did not result in less EI in the test meal, 1 h later. In addition, the active gaming EI of the boys was not offset by the estimated energy expended. Consequently, at the end of both 90 min gaming trials, REI was positive which then increased following consumption of the post-gaming test meal, although this was significantly higher for seated video gaming. Plasma GLP-1_{7-36} was

raised during both trials but did not differ significantly. Subjective sensations of hunger, prospective food consumption and fullness were also no different between trials. However, the subjective responses appeared to reflect the increase in GLP-1_{7-36} during 90 min of game play and decrease at cessation of both trials. These latter findings are consistent with those found between seated gaming and resting in male adolescents [14] and between seated video gaming and television viewing in 9-13 y boys [38].

In the present study, the total EI of the boys during 90 min of seated video gaming was 2.64 MJ, whilst in the active video gaming bout, EI was significantly lower (1.63 MJ). Per hour, the values obtained for seated video gaming (1.75 $MJ \cdot h^{-1}$) are identical to those found previously in 8-11 y boys (1.75 $MJ \cdot h^{-1}$) [11] although higher than those observed in 8-12 y children (1.57 $MJ \cdot h^{-1}$) [39]. For active video gaming, EI was less per hour (1.08 $MJ \cdot h^{-1}$) than previously established both in 8-11 y boys (1.41 $MJ \cdot h^{-1}$) [21] and 8-12 y children (1.60 $MJ \cdot h^{-1}$) [39]. Differences in EI between studies could be due to variations in study methodologies, since the current study was situated in the laboratory as opposed to the after-school setting employed in our previous work [21]. The more familiar and relaxed setting of the school might have induced greater EI [21]. In addition, Mellecker and McManus (2008) [39] utilised a seated video gaming device attached to a treadmill, instead of a genuine active video gaming console [39]. The mode of active video gaming was less realistic and so may have been less stimulating and challenging and this could have induced greater EI than observed presently. In the present study however, the lower active video gaming EI may have been due to the movement required for game play which could have made it more difficult to eat, than when playing the seated video game. In addition, the longer delay in time to eating onset during active video gaming, although not significant may help to explain the lower EI. In our previous work with 8-11 y males however, a significant delay was observed in time to eating onset (min) during active video gaming, yet EI was not significantly lower than when seated [11].

The EI of the boys during 90 min of active video gaming although significantly less than for seated video gaming, when compared to daily EAR for energy [37], was 34% and 21%, respectively of requirements. When accounting for the estimated EE during the bouts, the REI at cessation of seated and active video gaming was 2.26 MJ and 0.99 MJ, respectively. Allowing for the post gaming test meal, at the end of both trials, REI increased to 3.34 MJ for seated and 2.06 MJ for active video gaming. Although the boys did not compensate for the extra EI during active video gaming by down-regulating their EI at the test meal, the resultant energy surplus was 1.28 MJ lower than when the boys were seated. Nonetheless, the REI for both active and seated video gaming may

be clinically meaningful in relation to weight status, as a reduction of only 0.46 to 0.69 MJ per day may be all that is required to reduce the energy gap and decrease children's body mass [40].

As previously reported with television viewing, it is possible, that both seated and active video gaming could have a distractive effect which can lead to over-consumption of energy without an increase in appetite sensations [41]. Such an effect is thought to disrupt the habituation to food cues from the sensory, neuronal and digestive systems [41] and as a consequence satiety signals appear to be ignored thus causing over-compensation in EI for the energy expended [14; 38; 42]. In relation to active and seated video gaming, this disruption, coupled with an environment in which highly palatable foods are available *ad-libitum*, could have activated the brain's reward centre. As a result, satiety peptides might have been down-regulated and instead an augmented release of hormones associated with pleasure (dopamine, endocannabinoids and opiates) may have been increased. This response is related to hedonic systems and sustains the drive to eat [23].

The only paediatric study [16] thus far to have investigated compensation due to active video gaming EE, also did not establish any difference in EI in a post gaming meal, when compared with 1 h of resting and seated video gaming. In contrast to the present study, at the end of the active video gaming trial, the boys were in negative REI although this was compensated for 24 h later by an increase in EI [16]. However, food was offered *ad-libitum* in a post gaming test meal only and not both during and following each trial, as in the present study. From the current study, it is not known whether the boys compensated for the extra EI during both gaming trials at a later time, either by a down-regulation in EI or an increase in EE. If no compensation occurred, the REI established for both seated and active video gaming could contribute to a positive energy balance state and if it is a frequent behaviour, could lead to obesity and so pose a risk to child health. Further research should consider the effects of active video gaming on subjective and objective appetite over a longer time period, to establish if compensation for the extra EI occurs more than 1 h post in 8-11 y boys.

The higher time-averaged AUC concentrations of blood glucose and lower EI of the boys during active video gaming most likely occurred from the greater proportion of CHO consumed or the greater EE. However, greater concentrations of blood glucose are also in accordance with the 'glucostatic theory'. The responses of glucose and GLP-$1_{7\text{-}36}$ which increased over the course of the 90 min of active gaming may have enhanced satiety and caused this lower EI. Nonetheless, during both active and seated video gaming, EI was substantial and so an hedonic response should not be dismissed as this may have superseded the homeostatic signal of GLP-$1_{7\text{-}36}$ to stop eating, during

active video gaming [24; 43]. Future active gaming studies should therefore consider the measurement of insulin and hedonic food intake by VAS.

To the authors' knowledge, the present study initiated the investigation of the acute effects of active and seated video gaming on glucose and GLP-$1_{7\text{-}36,}$ in 8-11 y boys. In addition, fingertip capillary blood sampling was utilised to quantify GLP-$1_{7\text{-}36}$ as this was only recently established as a comparable option to the antecubital-venous method, [34]. Considering the age of the present study population (8-11 y), this alternative blood sampling technique provided a more suitable method for the collection of blood and thus assessment of GLP-$1_{7\text{-}36}$ and glucose.

The measurement of hormonal appetite during active video gaming in children is not without limitations. Due to the short half-life of GLP-$1_{7\text{-}36}$, to ensure it's preservation, the study was conducted in the laboratory rather than in a school setting as in our previous work [21; 44]. The levels of glucose which were significantly greater during active video gaming than when the boys were seated might also have stemmed from the low intensity exercise. As such, further research could include the measurement of lactate to assess the demands of active video gaming [45]. The present sample was limited to the study of boys only, due to physiological aspects primarily related to the different growth and maturation rates to girls during 8-11 y [46]. For this reason the authors believed it inappropriate to include girls, as to do this would have meant subdividing by gender and thus reducing methodological rigour. Future paediatric active video gaming research in relation to EI and appetite would therefore, benefit from work with girls.

To conclude, 90 min of active video gaming decreased EI, yet similar to seated gaming, REI was positive following 90 min of active video gaming and this was not compensated for in the post gaming test meal. Instead, the lack of compensation in the post-gaming test meal resulted in an increase in REI, which although reduced by 1.28 MJ due to active video gaming, is a clinically meaningful amount in terms of body mass [40]. Active video gaming and food and drink consumption should not therefore, be simultaneous behaviours in children, as this type of eating behaviour could counteract the health benefits of the higher EE, which may then lead to an increase in body mass.

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TABLES

Table 1

Table 1. Serving size, total energy and macronutrient values of food and drink items served during the gaming bouts.

Food or drink	Serving size	Energy (MJ)	Carbohydrate (g)	Fat (g)	Protein (g)
Apples ("Royal Gala" raw, sliced and cored)	130 g	0.26	15.60	0.13	0.52
Walker's© ready salted crisps	50 g	1.10	25.75	15.95	3.05
Semi-skimmed milk	250 mL	0.52	12.00	4.50	9.00
"Jucee" apple and blackcurrant squash (no added sugar)	250 mL (1:5 dilution)	0.03	2.50	0.00	1.30

Table 2

Table 2. Mean $_{\pm SEM}$ gaming EI (MJ), time to eating onset during gaming (min) PA METS, energy expenditure (EE) (MJ), gaming relative energy intake (MJ), test meal EI (MJ), total relative energy intake and ingestion time of test meal (min) for all boys (n=21) for each gaming trial.

	Seated video gaming		Active video gaming		
	Mean	**SEM**	**Mean**	**SEM**	***p* value**
Gaming EI (MJ)	2.65	0.32	1.63	0.26	<0.001*
Time to eating onset during gaming (min)	7.50	2.32	9.11	2.41	0.811
PA METS	1.22	0.04	1.99	0.11	<0.001*
EE (MJ)	0.39	0.01	0.64	0.03	<0.001*
Gaming relative energy intake (MJ)	2.26	0.32	0.99	0.26	<0.001*
Test meal EI (MJ)	1.08	0.12	1.07	0.10	0.859
Total relative energy intake (MJ)	3.34	0.35	2.06	0.30	<0.001*
Ingestion time of test meal (min)	11.02	4.53	8.48	3.33	0.051

*Indicates a significant difference between the active and seated video gaming trials.